

# SEMI-ANNUAL STATUS REPORT

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The present report covers the first half of the eleventh year of operation under the NASA Grants NGL 05-002-007 and NGL 05-002-207. The grants support work in two separate fields of study; this semi-annual status report is accordingly divided into two parts. A brief summary of the work in these sub-disciplines is given below in order to present a general overview of the work performed.

## SUMMARY

### I. Infrared Astrophysics (G. Neugebauer, E. Becklin and M. Werner)

The infrared research is divided into two related subjects, observations at wavelengths less than  $34\ \mu$  and millimeter wavelength observations. The shorter wavelength observations emphasize high spatial resolution studies of infrared sources in complex galactic regions, mainly associated with H II regions, where stars are thought to be forming. This was highlighted by the discovery of a new complex of infrared sources in the Orion Nebula; the cluster was subsequently found to be at the center of a molecular cloud. A broad range of galactic and extragalactic objects have also been observed. The Comet Kohoutek was measured over a large period of time in the 1- to  $20\text{-}\mu$  wavelength region; its thermal properties were seen to agree closely with those of Comet Ikeya-Seki (1965f). Combined

infrared and photoelectric studies of the Makarian galaxies have shown several of these to have a composite spectrum showing a large emission feature in the far infrared.

Steady progress has been made in the program of one millimeter photometry at the prime focus of the 200-inch telescope during twilight hours. The size of the beam has been reduced to 60" and this smaller beam has been used to scan the central regions of the 1-mm continuum source associated with the core of the Orion molecular cloud. The results indicate that the source is resolved in both right ascension and declination, with an angular size of  $40'' \pm 10''$ .

The program of developing detectors for this wavelength region has also progressed. The 1.5-mm diameter germanium bolometer most recently fabricated has a radiation NEP of  $5 \times 10^{-14}$  Watts/ $\sqrt{\text{Hz}}$  (an electrical NEP of  $1.5 \times 10^{-14}$  Watts/ $\sqrt{\text{Hz}}$ ) and yields four times better signal-to-noise than the detector which was used a year ago. Much of the detector work has been devoted to the development of "composite" bolometers, which should be more sensitive than the simple germanium bolometers; the initial laboratory results on the composite bolometers have been very encouraging.

## II. X-ray and XUV Astronomy (G. Garmire and P. C. Agrawal)

The XUV telescope was flown as a piggyback experiment to observe Comet Kohoutek in the  $584 \text{ \AA} \text{ He I}$  line. The rocket underperformed compared to the initial estimates and the comet was considerably less luminous than anticipated, thereby allowing only an upper limit to be set on the He content of the comet.

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The Henke tube and optical bench facility are completed and ready for making X-ray reflection and scattering tests of optical surfaces.

A new technique for reconstructing two dimensional surface brightness distributions with appropriate errors from individual strip scans has been developed. The determination of model parameters by fitting data in non-linear systems has been studied. Preliminary results show spectral parameter uncertainties are currently underestimated or incorrectly evaluated in much of the published literature.

I. Infrared Astrophysics (G. Neugebauer, E. Becklin, and M. Werner)

The infrared studies pursued under this grant cover observations over a wide range of wavelengths from  $1.2 \mu$  to  $1 \text{ mm}$ . As usual, observations were made of both galactic and extragalactic objects with telescopes ranging from the Mt. Wilson 24-inch to the 200-inch on Palomar. In addition, several measurements made in previous years were completely analyzed and submitted for publication; the occultation size determination of IRC +10011 is one example of such studies (Zappala et al. 1974) as is the reduction of the time behavior of NGC 4151 and other Seyfert galaxies for the year 1971 (Penston et al. 1974).

The extragalactic program received a new impetus as a result of the high  $10\text{-}\mu$  sensitivity now achievable on the 200-inch equipped with the  $f/72$  wobbling secondary. With this system, which requires good seeing to utilize small throughputs, it is possible to measure  $[10 \mu] = 6.5$  in 1 second ( $1\sigma$ ). As a result, many of the Makarian galaxies which have been under study in collaboration with J. B. Oke and L. Searle for several years have been remeasured at  $10 \mu$  with the high sensitivity system. It is now confirmed that the galaxies fall into at least 3 classes. Many Makarian galaxies are clearly optically related to Seyfert galaxies, but some show a very typical non-thermal spectrum throughout the visual and infrared regions while another class exhibits a large  $10\text{-}\mu$  flux peak after a fairly sharp drop at  $\sim 3 \mu$ . The division of infrared properties is apparently correlated with several optical properties which also seem to separate the classical Seyfert galaxies into two subgroups. Through these differences it may be possible to understand the underlying nature of the Seyfert galaxies and their place in the evolution of galaxies.

A major interest in the group has been with H II regions and in the study of areas where star formation is in progress. In general, the emphasis has been on high spatial resolution studies of regions which have been mapped at radio wavelengths. A completely new area where stars may be forming was discovered in the vicinity of the Orion Nebula. This area, which is about 12' north of the Trapezium, contains a cluster of at least 5 infrared sources. It is also a source of CO line emission for which reason it has been designated Orion Molecular Cloud 2 (OMC 2). An infrared map of OMC 2 is shown in figure 1. The cluster is in many ways similar to the Becklin-Neugebauer / Kleinmann-Low complex in that the sizes are similar and each contains both resolved and unresolved sources. The most striking difference is that the luminosity of OMC 2 is less than that of the BN/KL complex by a factor of 10-100. This precludes the stars being O type stars as is possibly the case with the stars being formed in BN KL. The new cluster was found accidentally while making measurements of infrared stars in Orion. Subsequently, an area of  $\sim 1^\circ \times 1^\circ$  was scanned at  $2.2\mu$  to see if other infrared complexes are present; the results were negative thus emphasizing the unique nature of the BN/KL cluster and OMC 2.

In addition to the 1- to 20- $\mu$  measurements, the study of OMC 2 included observations at 1 mm and in the CO and CS radio lines by N. Scoville. The 1-mm measurements were made as part of the millimeter program described below, utilizing the 200-inch prime focus during twilight times, and show that the flux at 1 mm into a 60" beam appears to be no greater than 10% of the flux from the Kleinmann-Low region. Since the

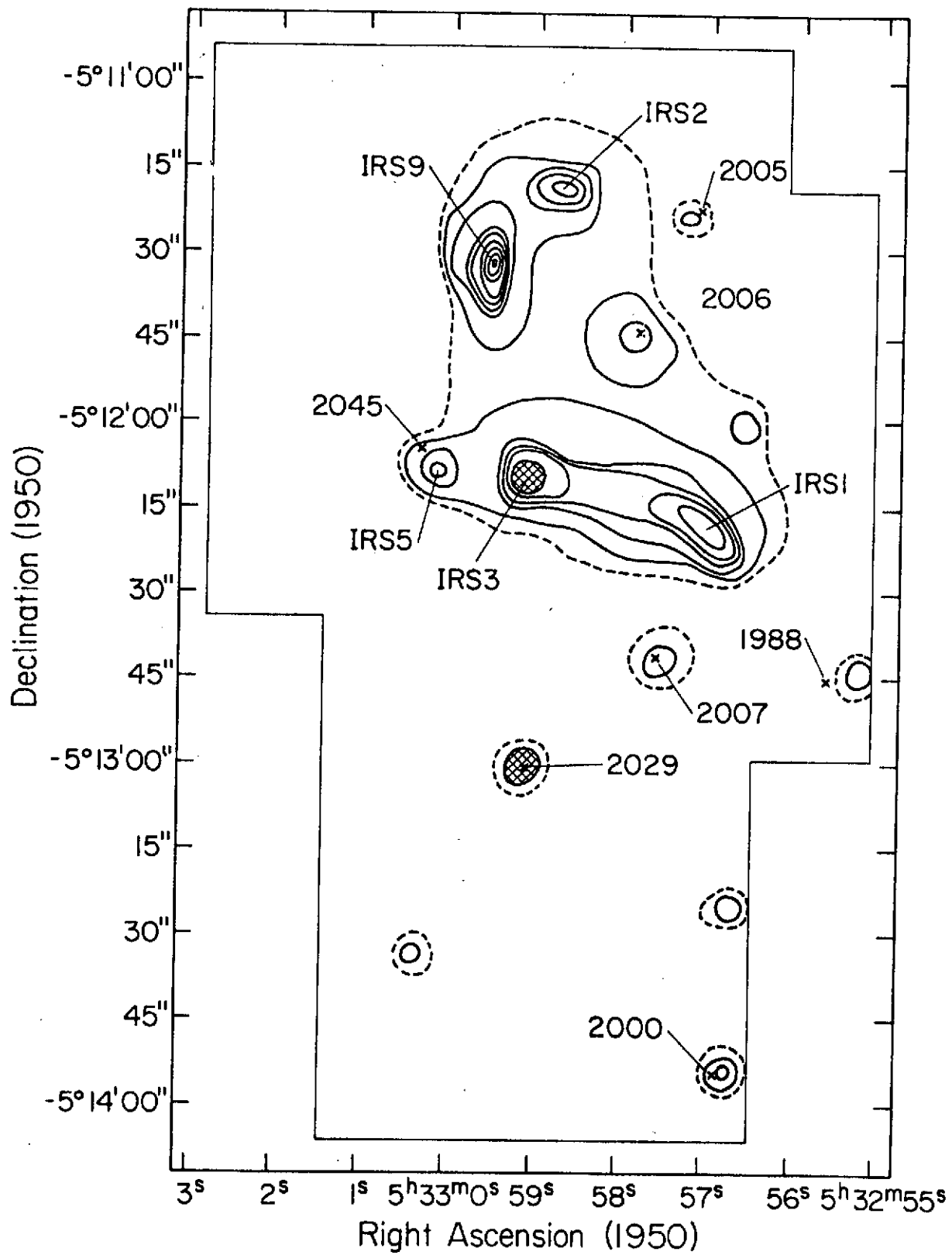


Figure 1

1-mm intensity is probably a good indicator of the total column density of matter along the line of sight, this suggests that the column density through OMC 2 is appreciably less than that through the Kleinmann-Low region.

One feature of the group's activity is that it has the availability of telescopes and maintains the flexibility to engage in long term concentrated observational programs. Such a program occurred during the appearance of Comet Kohoutek for which extensive observations were carried out using the 24-inch telescope at Mt. Wilson in the infrared photometric bands between  $1.2 \mu$  and  $20 \mu$ . Particularly for  $\lambda \geq 2 \mu$ , the infrared radiation from the comet is predominantly due to thermal emission from cometary dust particles heated by solar radiation; studies of the infrared radiation should help us to understand the nature both of these particles and of the dynamical processes occurring in comets.

The comet was first observed when it was 1 a.u. from the Sun and it was monitored as it passed through perihelion and until it was again 1 a.u. from the Sun. The brightness of the comet increased rapidly as it approached the Sun. At  $3.4 \mu$ , for example, the brightness varied as  $R^{-5.5}$ ,  $R$  being the comet-sun distance. At  $10 \mu$ , the brightness varied as  $R^{-3.5}$ . The slopes of the brightening lines are remarkably similar to those observed for Comet 1965f by Becklin and Westphal (Ap. J., 145, 1966), although at a given  $R$  Comet Kohoutek was a factor of two to three less bright than 1965f. Another point of similarity with 1965f is that both comets were  $\sim 30\%$  less bright at a given  $R$  following perihelion than when approaching the Sun; this may indicate that solar heating produces

a substantial loss of surface area by the comet during its closest approach to the Sun.

A broad emission feature is observed in the 10- $\mu$  region, suggesting that some of the emitting particles are composed of silicates. With the silicate feature removed, the underlying energy distribution of the comet in mid-December, when  $R = .435$ , is well fit by a 500°K black body curve between 3.5  $\mu$  and 20  $\mu$ . For comparison, a black or grey sphere at this distance from the sun would have a temperature of 425°K. The points at 1.6  $\mu$  and 2.2  $\mu$ , however, are well above both the 500°K black body curve and an extrapolation of reflected sunlight through the observed 1.2- $\mu$  point. The excess radiation at 1.6  $\mu$  and 2.2  $\mu$  indicates the presence of cometary dust particles which are much hotter, and presumably much smaller than those which emit the bulk of the energy in the 10- $\mu$  region.

One part of the exploratory program carried out by the infrared group involved the systematic study of sources found by the Air Force Cambridge Research Laboratory infrared rocket survey. This survey contains a number of unidentified sources, many of which are seen only at 10  $\mu$  and/or 20  $\mu$ . One such object was found on September 29, 1973, at the Mount Wilson 60-inch, during a program of examination of unusual AFCRL catalog listings, and was reobserved on October 18, 1973 at the 200-inch. The infrared properties of this object can be summarized as follows: 1) The object is quite faint in the near infrared, being 11.6<sup>m</sup> at 1.6  $\mu$  and 9.2<sup>m</sup> at 2.2  $\mu$ . However, the spectrum rises steeply to -2.3<sup>m</sup> at 10  $\mu$  and -4.7<sup>m</sup> at 20  $\mu$ . The overall spectrum is similar to that of the compact HII region K3-50 (Neugebauer and Garmire, 1970, Ap. J. Lett., 161, L91) and the H II



condensation W51-IRS2. 2) Scans at 10  $\mu$  and 20  $\mu$  show the object to be unresolved, and give an angular size upper limit of 1". In this respect the object is different from K3-50 and W51-IRS2. 3) The object shows no "silicate" feature. This result was confirmed by K. Merrill of the University of California at San Diego, who found that the 8- to 13- $\mu$  spectrum of the object was essentially flat. 4) Visually, two objects can be seen through the 200-inch. One object, apparently coincident with the infrared source, appears nebulous (diameter about 2") while the other, 6" away, appears stellar.

Optical spectra of both visual objects have been taken by M. Schmidt. The objects have similar spectra, indicating they might be associated. The spectra show many emission lines and are similar to spectra of compact HII regions. A visual extinction of about 3 magnitudes is implied from the ratio of [SII] lines and from the Balmer decrement. This is consistent with the absence of a "silicate" feature and rules out the possibility of the source being a reddened star. Analysis of the spectra has not yet been completed, but should yield information on electron density and temperature.

In light of the above observations, a very unusual property of this object is that it has not been seen at radio wavelengths, although C. G. Wynn-Williams of Cambridge has searched for it at 5 GHz. An upper limit of 12 mfu. has been placed on the object at this frequency.

The absence of a radio source, together with the other properties of this source, make the object unique. Further observations and data analysis will be necessary to help determine the nature of this object and to understand how it is related to other infrared sources.

In addition to the observations from the Northern Hemisphere, some data were obtained from Chile at the end of the last reporting period. The observations were highlighted by the 34- $\mu$  observations of  $\eta$  Carinae, G333.6 - a compact HII region -, and the galactic center. The measurements confirmed that the bulk of the infrared flux of  $\eta$  Car can be attributed to a 250<sup>o</sup>K circumstellar shell. The energy distribution of G333.6 rises smoothly to 34  $\mu$  which indicates that the emission probably comes from dust more or less uniformly distributed within and around the HII region rather than from a dust depleted HII region surrounded by an external dust region. The measurements of the galactic center show strong 34- $\mu$  emission and add support to the hypothesis that the infrared emission from the galactic nucleus is predominantly thermal reradiation from heated dust.

A major thrust of the group's activities was directed towards making observations at 1 millimeter in a continuation of the program using the 200-inch during twilight hours. The beam used for observations at 1-mm has been reduced in size to  $\sim 60''$ , close to the diffraction limit of the 200-inch. Despite this decrease in beam size, a number of changes in the system were made which resulted in a net improvement in sensitivity of a factor between 6 and 8. An appreciable factor in this resulted from the gain in detector sensitivity discussed below. The core of the molecular cloud associated with the Kleinmann-Low nebula in Orion has been scanned with this beam; the 1-mm radiation from this source is thought to be thermal emission from grains associated with the molecules in the cloud. The results indicate that the core is resolved in both right ascension and declination, with a characteristic angular scale of about 40''. The total flux of 1-mm continuum radiation into the 60'' beam centered on the

Kleinmann-Low Nebula is about 75% of the flux which was previously measured with a 100" beam, at least twice as much as would be expected to be seen if the source were uniformly bright on a scale of 100". Both these results indicate a considerable degree of central condensation in the center of the Orion molecular cloud. The degree of condensation may be related to the dynamical processes occurring in the cloud, and further investigations of this sort are planned.

A prominent feature of the program during the past year was the increased emphasis on detector development. The most conspicuous success was in the development of the InSb detectors for which background limited sensitivity at  $2.2 \mu$  was finally achieved. This means that several programs which previously could be done only on the 200-inch can now be shifted to the 100- and 60-inch telescopes.

Increased effort has also been put into the development of high sensitivity bolometers for detection of millimeter-wave radiation. A very significant gain in sensitivity has already been realized, close to a factor of 4 over the bolometers previously made here, and further substantial gains are expected.

This development program was stimulated by three considerations:

(1) for reasonable values of bandwidth and spatial resolution, there is a large gap between the sensitivity of available millimeter-wave bolometers and the fundamental limits imposed by background emission for ground-based telescopes, and an even larger gap for space-based telescopes. Closing

this gap will increase millimeter-wave observational capabilities more than any other foreseeable technical advance; (2) present technology permits the construction of composite bolometers using semiconducting temperature sensors which, for given operating temperature, area, and response time, can be made to approach background-limited operation more closely than conventional semiconducting bolometers; and (3) new superconducting technology makes possible the fabrication of composite bolometers. In addition, these superconducting junctions have been under investigation as potential coherent millimeter-wave detectors, and the composite superconducting bolometer will be helpful in evaluating the practicality of these junctions for applications outside the low-temperature physics laboratory.

So far efforts have been concentrated on building improved conventional bolometers and on fabricating composite bolometers with semiconducting temperature sensors. One bolometer of each type approximately four times as sensitive to millimeter-wave radiation as the bolometers previously used for astronomical observations at the 200-inch telescope has been produced. These new bolometers have far-infrared NEPs, measured at a chopping speed of 10 Hz, of  $\sim 5 \times 10^{-14} \text{ W Hz}^{-1/2}$ , and response times of 10 and 7 msec respectively. The conventional bolometer consists of a 1.5-mm diameter piece of In-doped Ge (Sb compensated), and performs better than previous Ga-doped Ge bolometers primarily because the new material gives higher responsivity and higher far-infrared absorption. The initial composite bolometer design consists of a 2-mm x 2-mm radiation absorber (thin sapphire with Bi film coating for absorption) to which

is fastened a small Ge chip to sense the temperature changes. The essential advantage of the composite bolometer over the conventional design arises from the possibility of building an efficient absorber having a much lower heat capacity than that of the single-element bolometer of the same area. We have produced composite bolometers with heat capacity close to our design goal of  $2 \times 10^{-9} \text{ J K}^{-1}$  and with constant radiation absorption efficiency of 50% over a broad spectral range. In spite of relatively high noise in the Ge chips used on the composite bolometers so far, sensitivity equal to that of the best new conventional bolometers has been achieved. Presently about two such composite bolometers are being produced and tested per week, and the radiation NEP is expected to be pushed below  $1 \times 10^{-14} \text{ W Hz}^{-1/2}$  with only minor changes in design.

Other improvements in the equipment have also been achieved. Most notable are the attachment of a television camera with a wide field of view to the f/72 system plus the construction of a data system which will move the telescopes automatically in synchronization with the data taking. Both of these systems are being tested at the present time.

During this year two visitors, R. Zappala and G. Veeder completed their programs using the infrared equipment. T. Johnson, D. Matson and G. Veeder incorporated infrared measurements as part of their study of asteroids. Selected asteroids are being observed at 0.56, 1.6, and 2.2  $\mu$ . These observations are being combined with 0.3- to 1.1- $\mu$  data in the literature to produce 0.3- to 2.2- $\mu$  reflectivity curves. Recent laboratory studies at JPL have indicated that this extended wavelength coverage is

crucial for testing compositional hypotheses. Preliminary results have confirmed the presence of carbonaceous chondritic material on the surfaces of the first two numbered asteroids (Ceres and Pallas). Seven other asteroids have been observed and the data is now being reduced.

Twelve mutual events (occultations and eclipses) of the Galilean satellites of Jupiter were observed by Matson, Johnson and Loer using the 60-inch telescope on Mt. Wilson. Before these observations, the positions of these satellites given by Sampson's theory were uncertain by 1000 km; with the help of T. Duxbury of JPL, the new data were used to reduce this error to 50 km for Io (J1). This new information was used in the navigation of Pioneer 10, and resulted in the successful occultation of the spacecraft by Io. Orbits for the other satellites are being updated and when this is completed it will then be possible to reduce the observations further and to extract crude albedo maps for the satellites.

## II. X-ray and XUV Astronomy (G. Garmire and P. C. Agrawal)

On 5 January the XUV telescope, which has been developed through this contract, was flown as a piggyback experiment with Dr. Fastie's payload from John Hopkins University to observe Comet Kohoutek in the  $584 \text{ \AA} \text{ He I}$  line. The calculations and a small amount of instrument modifications by CIT were supported by this contract. The instrument performed well, but the rocket only carried the experiment to 235 km, which was well below the anticipated 300 km altitude. This resulted in a much greater attenuation of the  $584 \text{ \AA}$  flux than expected since the comet was at low elevation during the flight.

A Henke style X-ray tube has been constructed with help from Professor R. Novick who visited Caltech during the Fall quarter. The tube works quite well and is now being installed in a 30 x 120-inch vacuum chamber to be used for testing X-ray mirrors. The mirrors were produced by using a diamond knife on an airbearing spindle lathe at the Oak Ridge Y-12 Lab to cut the copper surface overlaying the aluminum mirror. The copper was then overcoated with electroless nickel. Various lapping processes will be used to study how well the reflection and scattering properties of these surfaces can be optimized using the X-ray test facility for evaluation purposes. Once the lapping techniques are satisfactory, they will be applied to the optical surfaces of the X-ray telescope that is being prepared for flight on an Astrobee F rocket.

A new method of reconstructing surface brightness maps of the X-ray sky from one dimensional strip scans has been developed. It is based on linear regression analysis and follows the work of A. Klug and R. A. Crowther (Nature 238, 435, 1972). The X-ray data from the Vela-Puppis

region is being analyzed using this method. The method has a number of advantages over the previously used one (Stevens and Garmire, Ap. J. 180, L19 (1973)) in that it allows an analytical determination of the errors in the reconstruction process as well as prescribes the highest possible resolution which can be achieved for a given collimator response and scan pattern. After reducing the data on the Vela-Puppis region, the data on the Cygnus Loop will be reanalyzed if sufficient manpower is available.

A careful study has been made to re-evaluate the precision to which spectral parameters can be determined when the analysis involves highly non-linear terms, as is the case in X-ray spectral fitting with proportional counters. The technique proposed by Cline and Lesser (Nucl. Inst. Methods 82, 291 (1970)) was evaluated for data obtained on Sco X-1 during the Nike-Apache flight 14.415. The technique for evaluation used randomly generated data based on the actual flight data parameters. From this analysis it is clear that the proposed method of Cline and Lesser is better than the common practice (Gorenstein et al., Ap. J. 153, 885 (1968)). However, the method is not perfectly accurate for cases involving extreme nonlinearity such as the determination of spectral cut-off data. The difficulty lies with the fact that the cut-off is determined by only one or two data points, whereas the statistical test may involve up to twenty or so points most of which are completely insensitive to the parameter under investigation. Work on this problem is continuing.



BIBLIOGRAPHY

- Agrawal, P. C., Long, K., and Garmire, G. P. "Observation of Soft X-Ray Emission from Per X-1," 1974, Astrophys. Space Sci., (in press).
- Agrawal, P. C., Moore, W. E., and Garmire, G. P. "A Rocket Borne Instrument for the Study of Soft X-Ray Emission from Cosmic X-Ray Sources," 1973, Proceedings of the 13th International Cosmic Ray Conference, (Denver, Colorado), 4, 2697.
- Becklin, E. E., Frogel, J. A., Kleinmann, D. E., Neugebauer, G., Persson, S. E., and Wynn-Williams, C. G. "Infrared Emission from the Southern H II Region H2-3," 1974, Ap. J., 187, 487.
- Becklin, E. E., Hansen, Olav, Kieffer, H., and Neugebauer, G. "Stellar Flux Calibration at 10 and 20  $\mu$  Using Mariner 6, 7, and 9 Results," 1973, Astron. J., 78, 1063.
- Becklin, E. E., Hawkins, F. J., Mason, K. O., Matthews, K., Neugebauer, G., Sanford, P. W., and Wynn-Williams, C. G. "Infrared and X-Ray Variability of Cyg X-3," 1973, Nature Phys. Sci., 245, 302.
- Becklin, E. E., Kristian, J., Matthews, K., and Neugebauer, G. "Measurements of the Crab Pulsar at 2.2 and 3.5  $\mu$ ," 1973, Ap. J. (Letters), 186, L137.
- Becklin, E. E., Matthews, K., Neugebauer, G., and Wynn-Williams, C. G. "The Size of NGC 1068 at 10  $\mu$ ," 1973, Ap. J. (Letters), 186, L69.
- Becklin, E. E., Neugebauer, G., and Wynn-Williams, C. G. "The Spatial Distribution of the Infrared Emission from NGC 7027," 1973, Astrophys. Letters, 15, 87.
- Harvey, Paul M. "Infrared Variability of V1016 Cygni," 1974, Ap. J., 188, 95.
- Harvey, Paul M., Bechis, Kenneth P., Wilson, William J., and Ball, John A. "Time Variations in the OH Microwave and Infrared Emission from Late-Type Stars," 1974, Ap. J., 187, 491.
- Harvey, P. M., Gatley, I., Werner, M. W., Elias, J. H., Evans, N. J., II, Zuckerman, B., Morris, G., Sato, T., and Litvak, M. M. "Dust and Gas in the Orion Molecular Cloud: Observations of 1-mm Continuum and 2-cm H<sub>2</sub>CO Emission," 1974, to be published in Ap. J. (Letters).

- Johnson, Torrence V., Matson, Dennis L., Veeder, G. L., and Loer, S. J. "Asteroid (1) Ceres: A Carbonaceous Chondrite?" 1973, E.O.S., 54, 1124.
- Moore, W. E., Agrawal, P. C., and Garmire, G. "An Upper Limit on Soft X-Ray Pulsations from the Pulsar PSR 0833-45," 1974, Ap. J. (Letters), (in press).
- Moore, W. E., Cordova, F., and Garmire, G. P. "A Rapid Change in the Low Energy Cut-Off of Scorpius X-1," 1973, Proceedings of the 13th International Cosmic Ray Conference, (Denver, Colorado), 1, 56.
- Neugebauer, G. "Infrared Capability with the LST," 1974, January, Proceedings of the American Institute of Aeronautics and Astronautics, (Washington, D.C.), to be published.
- Penston, M. V., Penston, Margaret J., Selmes, R. A., Becklin, E. E., and Neugebauer, G. "Broad-Band Optical and Infrared Observations of Seyfert Galaxies," 1974, submitted for publication in M.N.R.A.S.
- Riegler, Guenter R. and Garmire, Gordon P. "Observations of the Extreme Ultraviolet Nightglow," 1974, J. Geophys. Res., 79, 226.
- Sutton, E., Becklin, E. E., and Neugebauer, G. "34- $\mu$  Observations of  $\eta$  Carinae, G333.6-0.2 and the Galactic Center," 1974, to be published in Ap. J. (Letters).
- Westphal, J. A., Matthews, Keith, and Terrile, Richard J. "Five Micron Pictures of Jupiter," 1974, Ap. J. (Letters), (in press).
- Wynn-Williams, C. G., and Becklin, E. E. "Infrared Emission from H II Regions," 1974, P.A.S.P., 86, 5.
- Wynn-Williams, C. G., Becklin, E. E., and Neugebauer, G. "Infrared Studies of H II Regions and OH Sources," 1974, Ap. J., 187, 473.
- Wynn-Williams, C. G., Werner, M. W., and Wilson, W. J. "Accurate Positions of OH Sources," 1974, Ap. J., 187, 41.
- Zappala, R. R. "On the Nature of BD-10<sup>0</sup> 4662," 1974, Ap. J., 187, 257.
- Zappala, R. R., Becklin, E. E., Matthews, K., and Neugebauer. "Angular Diameter of IRC+10011 at 2.2, 10 and 20  $\mu$ ," 1974, to be published in Ap. J.

Note: Some of the above articles have appeared in previous status reports but have only been published in the past six months.